The airborne radioactivity and electrical properties of ground level air

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Abstract The data presented in this work are the result of systematic measurements of radionuclide concentrations in air, collected with an ASS-500 high volume air sampler of the ground air monitoring network supervised by the Central Laboratory of Radiological Protection. Sampling has been done since March 1991. Simultaneously, the routine complex meteorological observations were performed. In particular, the electrical properties of ground level atmospheric air were studied with measurements of electrical field intensity, positive and negative conductivity of air and density of vertical current. The airborne ^{7}Be concentration changes similarly to the electrical conductivity of air, while other isotopes, antropogenic or originating from the ground are correlated with dust and other meteorological factors like watering and wind.

Key words aerosols • air monitoring • radioelectricity • radionuclides

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Introduction

It has been known that electric conductivity of atmospheric air is related to large scale processes which take place in different regions of higher and lower atmosphere. Ionization caused by the presence of cosmic rays, UV, radioactive isotopes of natural or antropogenic origin and a broad range of air pollution influence the electrical properties of air. Radionuclides introduced in to the atmosphere regardless of their origin cause an increase of radioelectricity in air and air conductivity which is determined by ion concentrations, their mobility and charge [1]. There are three separate sources of radioactivity in the atmosphere. The first deals with the emanation of radon and thoron, their escape into air from the ground and the formation of their radioactive decay products in the atmosphere. Some of long-lived decay products are useful tracers for the worldwide stratospheric circulation and global distribution. The next one contains radionuclides generated by cosmic rays primarily within the upper troposphere and lower stratosphere. The list of nuclear reactions induced by cosmic rays in air is very long but ^{7}Be production processes play a dominant role in the air conductivity. The last group are radionuclides of antropogenic origin, coming from the release from nuclear facilities, nuclear fuel reprocessing plants, nuclear weapon tests and nuclear accidents. They gained a wide public interest because of the potential hazard of large-scale radioactive fallout. The global problems are now clearly recognised and the meteorology needs more and more data about the phenomena which take place on a large scale like circulation, horizontal transport of radionuclides, removal and residence time in ground level air.

In general, electrical conductivity of air is a function of ion concentrations in air, their mobility and deposited charge. In the ground level air as a result of natural radioactivity, on an average, are created [2, 3] 10–12 pairs of ions/cm^3/sec out of which:

- 4 pairs of ions/cm^3/sec are due to radionuclides in the ground,
- 5 pairs of ions/cm^3/sec due to radionuclides in air,
- 1–2 pairs of ions/cm^3/sec due to cosmic rays.

Other ionising factors like UV, X-rays play a significant role at altitudes of 60–70 km and high energy particles coming from the magnetosphere influence air ioniziation in regions near the Poles [5].

The change of light ions concentration in air is described by the ion equations

$$(1) \quad \frac{dn}{dt} \cong q - \alpha n^2 - \beta z n$$

where: n – light ion concentration, q – ionization coefficient, β – effective factor of light ions attachment to aerozol particles (2×10^{-6} cm^3/sec^{-1}), α – recombination coefficient, z – concentration of aerosol particles.

In the stable state for

$$(2) \quad \frac{dn}{dt} = 0$$

we obtain

$$(3) \quad n \cong \frac{\left[1 - \beta z + \left(\beta^2 z^2 + 4\alpha q\right)\right]^{1/2}}{2\alpha}$$

It is evident from this equation that for constant z increase of q causes increase of n.

Experimental methods of electrical conductivity measurements and radionuclides monitoring of ground-level air

The measurements of electrical properties of ground level air and radionuclide concentration were performed at the territory of Geophysical Observatory at Świder where numerous geophysical data have been collected during more than 50 years and published in publications of the Institute of Geophysics of Polish Academy of Sciences, e.g. [4]. The following measurements are recorded:

- intensity of electrical field in the ground level air,
- positive and negative conductivity of air,
- vertical current density,
- concentration of aerosol particles,
- radioactivity of air, soil, grass and rainwater,
- gaseous pollution of air with CO_2, SO_2 and dust,
- complex meteorological measurements.

Electrical conductivity of air, which is a function of ion concentrations, their mobility and charge was measured using so called aspirating method of Gardien described elsewhere with a cylindrical condensator at constant air-flow [4]. The light ions are attracted to the inner polarized electrode and the ion current is measured by a high resistant $\sim 10^{11}\ \Omega$ resistor.

The radioactivity measurements were done using an ASS-500 high volume air sampler belonging to the ground level monitoring network in Poland supervised by the Central Laboratory for Radiological Protection. Aerosol was collected on a Petrianov filter tissue exposed to air-flow. Filters were weekly changed, dried and pressed to standard pellets and γ spectra were measured using a high resolution and high volume HP Ge ORTEC detector placed in a low background chamber. A typical γ spectrum is presented in Ref. [6].

Results and discussion

The concentrations of different radionuclides collected by this station in 1999 are presented in Fig. 1. As mentioned above, one can identify radionuclides of different origin: airborne ^{7}Be, long-lived ^{210}Pb, a decay product of radon exhaled from soil, surface soil component ^{40}K and man-made ^{137}Cs. The radioactivity collected on Petrianov filter, is a weekly integral effect. The concentrations of different radionuclides collected at the ASS-500 sampling station show dominant contribution of airborne ^{7}Be with typical summer maxima recorded also by all other aerosol sampling stations in Europe. The above results were compared with electricity measurements done at 30 sec intervals. Fig. 2 presents the ^{7}Be concentration in ground level air and the electrical conductivity changes. These are the seasonal changes, particularly the summer intensity maximum and

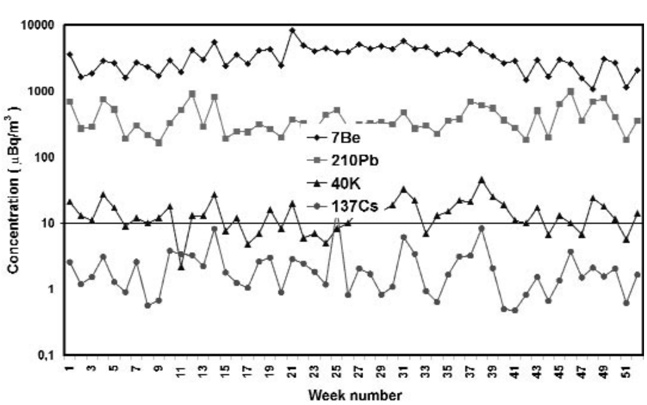

Fig. 1. The concentration of radionuclides in ground level air measured in 1999 at the Świder ASS sampling station.

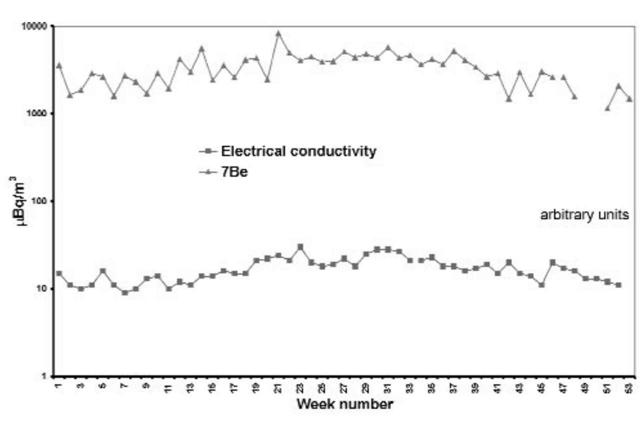

Fig. 2. Comparison of ^{7}Be weekly concentration in ground level air with electrical conductivity (arbitrary units) in 1999.

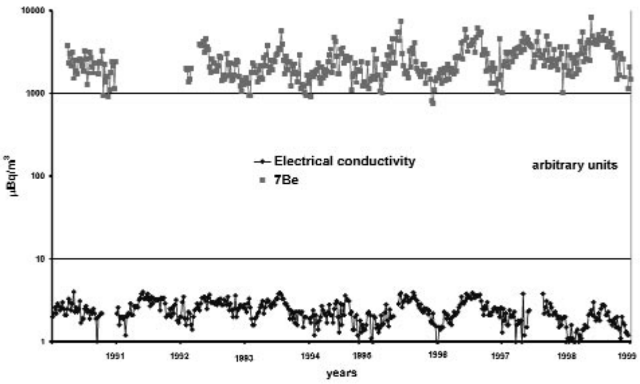

Fig. 3. Comparison of ^{7}Be weekly concentration with electrical conductivity during the 1991–1999 period.

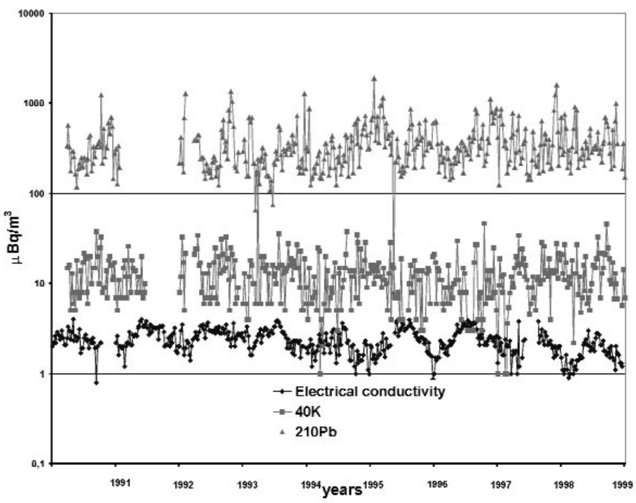

Fig. 4. The weekly concentration of ^{40}K and ^{210}Pb and electrical conductivity of air in the 1991–1999 period.

the minimum in winter time where both magnitudes overlap. This sequence is even more explicit on a longer time scale in Fig. 3 where results of several years of observation are presented. It would be interesting to make a similar comparison for a much longer time so that the influence of solar cycles could perhaps be noticed. However, there are no such data collected elsewhere where ^{7}Be concentration and air conductivity would be measured simultaneously. Comparison of the results from different places may depend very much on air mass transport phenomena.

No relation is seen between conductivity changes and concentrations of other radionuclides not airborne but coming from the soil surface like ^{40}K or the daughter products of

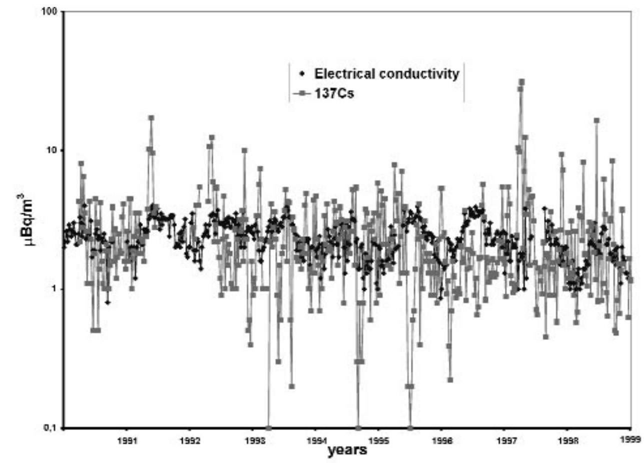

Fig. 5. The antropogenic ^{137}Cs weekly concentration changes with electrical conductivity for the 1991–1999 years.

Rn exhaled from the ground (see Fig. 4). This can be as well a result of the fact that concentrations of these isotopes in comparison with ^{7}Be are one or two orders of magnitude lower. The ^{137}Cs concentration of antropogenic origin in air is now about 3–4 orders of magnitude lower than ^{7}Be concentration and it does not affect the electrical properties of ground level air, which is shown in Fig. 5.

It seems that the study of atmospheric electricity can yield a complementary information useful for forecasting of radioactivity transport in air and for better understanding of the global phenomena which could influence the climate changes.

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